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Indian Standard

OPTICAL INSTRUMENTS—PERMISSIBLE COSMETIC DEFECTS AND INSPECTION OF OPTICAL COMPONENTS

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NEW DELHI 110002

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Optical and Mathematical Instruments Sectional Committee, LMD 20

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards on 7 June 1989, after the draft finalized by the Optical and Mathematical Instruments Sectional Committee had been approved by the Light Mechanical Engineering Division Council.

Since long, a need has been felt to specify the requirement for permissible limits of scratches and digs on optical components. As an optical element is the transmitting agent of light from an object to form an image, the necessity to lay down a standard for the quality of surface of the optical component is of considerable importance both for the manufacturer and the inspector/customer.

This standard describes the commonly recognized types of defects, namely, scratches, digs, and dust on the surfaces of optical components, and the methods of acceptance tests.

This standard is one of a series of Indian standards for optical instruments and is a necessary adjunct to the individual specifications for the different types of optical instruments.

This specification is based on international standards accepted and widely used by all the manufacturing agencies of optical components and optical instruments.

Indian Standard

OPTICAL INSTRUMENTS—PERMISSIBLE COSMETIC DEFECTS AND INSPECTION OF OPTICAL COMPONENTS

1 SCOPE

1.1 This standard deals with the cosmetic quality of finished optical components, such as lenses, prisms, mirrors, reticles, and with permissible defects on the surface of the optical element for different locations, and also deals with the methods of testing.

2 REFERENCE

IS No.	*Title*
IS 1399 : 1959	Glossary of terms used in optical technology

3 TERMINOLOGY

3.1 For the purpose of this standard, the following definitions in addition to those given in IS 1399 : 1959 shall apply.

3.2 Surface Defects

Imperfections of quality of optical surfaces including coated surfaces in the form of scratches, digs, dust or other blemishes fall into two main categories, namely, functional defects that are either situated in the immediate neighbourhood of an image plane or that may contribute to a reduction in system performance (for example, by causing scatters) and cosmetic defects that are objectionable solely on aesthetic grounds.

3.3 Scratch

Any marking or tearing of the surface. Scratch types are identified as follows:

a) *Block Reak*, chain like scratch produced in polishing,

b) *Runner Cut*, curved scratch caused by grinding,

c) *Sleek*, hairline scratch, and

d) *Crush or Rub*, series of small scratches caused by mishandling.

3.4 Dig

A small rough spot on the surface similar to pits in appearance.

3.5 Dust

Dust or non-transparent particles are classified as digs while considering surface quality.

3.6 Infections

Any imperfections on the optical surfaces that cannot be referred as scratches or digs or dust, for example, blemishes in the AR coating, dry marks, etc.

3.7 Material Defects

Bubbles or flaws in the material if they are cut into by the surface finishing operations are regarded as surface defects.

4 DESIGNATION

4.1 Scratch Number (s)

It is the actual width of the scratch, specified in units of 0·000 1 mm. The normal scratch numbers are 10, 20, 30, 40, 60, 80, 100, 120, 150, 200, 300, 400 and 500.

4.1.1 Actual scratch width for each number is :

Scratch Number (*s*)	*Scratch Width* (μm)
10	1
20	2
30	3
40	4
60	6
80	8
100	10
120	12
150	15
200	20
300	30
400	40
500	50

4.2 Dig Number (D)

It is the actual diameter of the dig allowed, specified in units of 0·01 mm. The normal dig numbers are 1, 2, 4, 5, 10, 15, 20, 30, 40, 50, 60 and 80.

4.2.1 Actual dig diameter for each number is:

Dig Number (*D*)	*Dig Diameter* (mm)
1	0·01
2	0·02
4	0·04
5	0·05
10	0·1
20	0·2
30	0·3
40	0·4
50	0·5
60	0·6
80	0·8

NOTE — The above dimensions of scratches and digs are specified for the calibration of master scratch standards only and not a means for measuring scratch or digs. Tolerance ± 10 on scratch and dig number shall be allowed in the calibration of the master standards.

4.3 Optical Drawing and Diagrams

Component optical drawings shall indicate surface quality, and optical system diagrams shall indicate the diameter of an axial beam of rays.

4.4 Surface Quality

Limiting sizes of the surface defects shall be designated on drawings by two numbers which refer to two grades sets of surface quality standards (for example, 60-30). The first number shall refer to scratches and the second number shall refer to digs.

5 GENERAL REQUIREMENTS

5.1 Scratches

5.1.1 The combined length of maximum size scratch located on each surface of an optical element situated near the image plane shall not exceed one-quarter of the clear aperture of that element and combined length of other size of scratches also should not exceed one-quarter of the clear aperture of the element provided the scratches do not accumulate at one place.

5.1.2 The combined length of scratches of all sizes located on each surface of optical elements other than those specified in **5.1.1** shall not exceed four-fifth of the clear aperture, and preferably they should not accumulate at one place.

5.1.3 The computing diameter of element shapes other than circular shall be that of a circle of equal area.

5.1.4 Scratches beyond the free aperture of any element as given in the drawing shall not be considered when computing the total length of all the scratches specified in **5.1.1** and **5.1.2**.

5.1.5 Areas of surfaces whose specified scratch qualities are 20 or better shall have no conglomeration of scratches such that in any 0·5 mm diameter circular area, there are more than 4 separate scratches.

5.1.6 Coating scratches which do not penetrate the glass surface, shall be within the same limits specified in **5.1.1** and **5.1.2**.

5.1.7 Scratches of width less than 0·001 mm are not to be taken into account for focal plane components and they will be termed as indiscernible scratches.

5.1.8 Scratches of width less than 0·002 mm are not to be taken into account for assessment for non-focal plane surfaces and they will be termed as indiscernible.

5.1.9 Coating scratches which do not penetrate the glass surface shall be within the same limits as specified in **5.1.1** and **5.1.2**.

5.2 Digs

5.2.1 The permissible number of maximum size digs shall be one per each 20 mm diameter or fraction thereof on any single optical surface. The sum of the diameters of all digs as estimated shall not exeed twice the diameter of the maximum size specified per 20 mm diameter. Digs less than 5 μm shall be ignored.

5.2.2 All digs on each surface whose dig quality is number 10 or less shall be separated edge to edge by at least 1 mm. The measurement of scattering is not required for surfaces where digs larger than number 10 are allowed.

5.2.3 Cement bubbles, voids, undissolved particles, dirt (lint or dust) within the free aperture of the cemented surface shall not exceed the limits of defects for digs specified in **5.2.1** and **5.2.2**. The cement interface is considered a single surface of the specified surface quality.

5.2.4 Digs of diameter less than 0·001 mm shall not be taken into account for evaluating of surface defects for focal plane components and they will be termed as indiscernible digs.

5.2.5 Digs of diameter less than 0·003 mm are not to be taken into account for assessment for non-focal plane surface and they will be termed as indiscernible.

6 SURFACE QUALITY

6.1 Lenses

6.1.1 Surface quality of each lens shall be in accordance with applicable drawings or instrument specification. When not specified, the surface quality shall be determined from Table 1.

Table 1 Surface Quality of Lenses

Position	Central Zone	Outer Zone
Objectives, erectors, condensers windows and other elements which lie at least 15 diopters out of the focal plane	80-50	80-50
Field and collective lens	20-10	40-20
Central lens and eye lens of eyepiece	40-20	60-30

6.1.2 The central zone shall be half of the clear aperture.

6.1.3 Edge chips which do not encroach on the free aperture of the lens shall be allowed provided the chip does not interfere with the sealing of the lens in the mount. The surface of all chips larger than 0·5 mm, as measured at the largest extremities, shall be 'stoned' to roughen it and lessen the possibility of annoying reflections and additional chipping. The sum of chip widths of chips larger than 0·5 mm, as measured at the edge of the lens, shall not exceed 10 percent of the perimeter. Fractures in excees of 0·5 mm depth in any face or edge shall be ground out. Ground out area shall remain within the applicable stoned chip limits of this paragraph. Fractures in excess of these limits shall be a cause for rejection. Stoned chips and fractures in ground faces whose total summed up areas are in excess of 2 percent of the area of the ground face or which are in excess of 2 mm depth shall be a cause for rejection. Such stoned chips and fractures shall be a cause for rejection when they interfere with the optical path or mounting or sealing methods regardless of their size.

6.2 Prisms and Mirrors

6.2.1 Surface quality of each prism or mirror surface shall be in accordance with applicable drawings or instrument specifications. When not specified, the surface quality shall be in accordance with Table 2.

Table 2 Surface Quality of Prisms and Mirrors

Position	Central Zone	Outer Zone
Surfaces which lie at least 15 dioptres out of the focal plane	60-40	80-50
Surfaces which lie within 5 to 15 dioptres out of the focal plane	20-10	40-20
Surfaces within 5 dioptres of the focal plane	Same as for reticles	

6.2.2 *Edge Chips*

Edge chips which do not encroach on free aperture of the prism shall be allowed within the following limitations. The sum of the chip widths shall not exceed 10 percent of the length of edge on which the chips occur. Chips shall be measured from the bevelled edge, and not from the sharp edge; that is, after bevelling and not before. Chips less than 0·5 mm shall be stoned. Encroachment of chips shall be measured on the faces of the prism from the bevelled edges. If the nominal length (measured to sharp corner before bevelling) of the shortest edge of the prism which is adjacent to any polished face is 25 mm or less, chips may encroach the faces 1 mm; if said length exceeds 25 mm, chips may encroach 2 mm. This shall be permissible provided that there are not edge chips which interfere with the mounting methods, or sealing or are vulnerable to shock and vibrations normally encountered and the chips do not encroach upon the free aperture.

6.2.3 Aperture surfaces of prisms through which light is to be transmitted shall be free from particles of silver or aluminium remaining from processing of other surfaces.

6.2.4 Defects on reflecting surfaces that appear the same as defects on other optical surfaces shall be treated in the same manner as specified in **6.2.1**.

6.3 Reticles

6.3.1 The surface quality shall be as specified on the drawings. When not specified, the surface quality shall be in accordance with Table 3. The central zone shall be the central area, three-fourths of the free aperture for reticles having reticle graduations and one-half of the free aperture for reticles having horizontal and vertical lines without graduations. Imperfections beyond the free aperture shall be permitted provided their characteristics do not impair the performance of the instrument.

6.3.2 Edge chip limitations shall be evaluated in accordance with **6.2.2.**

6.3.3 For an illuminated reticle, if the brightness of a defect is equal to or greater than the brightness of a reticle line, the defect shall be a cause for rejection.

6.3.4 Reticle markings shall be viewed through an eyepiece of essentially the same power under which the reticle will be viewed in the finished instrument. Letters and numerals shall be inspected primarily for legibility. Defects in numbers or letters shall be acceptable provided each letter or figure is legible beyond doubt. Unless otherwise specified, any printing style is permitted for the letters and numbers; however, the style selected must be uniform throughout each reticle and must meet with the approval of the procuring agency. Line breaks one-half of the width of the line shall be permitted. And one break per 5 lines or less shall be permitted. All lines shall appear to be of uniform width and depth and intersections of lines shall appear to be sharp. Smooth or abrupt variations in line width along the entire line shall not be in excess of 20 percent of the line width. In addition, bowed lines shall be within dimensional requirements and in no case shall reticle line be bowed in excess of one-half the reticle line width. The fillet radius at the intersection of reticle lines shall not exceed the line width. Acid burns shall be a cause for rejection, if visible when reticle is viewed with appropriate eyepiece.

6.4 Limiting Size of Surface Defects

6.4.1 If not specified on drawings, the limiting size of scratches or digs shall be determined from

Table 3 and is based on the beam diameter of magnification.

Table 3 Plane for Determining Surface Defects Based on Beam Diameter

(*Clauses* 6.3.1, 6.4.1 *and* 6.4.3)

Plane for Beam Diameter (mm)	Central Zone (One-half Free Aperture)	Outer Zone
0-1	10- 1	15- 3
1-3	20- 5	30-10
3-5	30-10	40-20
5-10	40-20	60-20
10-25	60-20	60-40
Over 25	80-50	80-50

6.4.2 The beam diameter shall be obtained from the optical data. It is the diameter at the surface of the optic in question, of a bundle of axial rays proceeding to the observer's eye. The diameter of the bundle at the eye shall be taken as 3·5 mm if the exit pupil is over 3·5 mm. If the exit pupil is smaller than 3·5 mm, the diameter of the bundle at the eye shall be the same as the exit pupil.

6.4.3 When the beam size is less than that specified in Table 3 focal planes and near focal planes of any surface, the size of defect is determined by the magnification of the eyepiece or of the eyepiece multiplied by magnification of the erecting system as specified in Table 4.

Table 4 Plane for Determining Surface Defects based on Magnification

Magnification	Central Zone	Outer Zone
4-6	30-5	40-5
7-10	20-3	30-5
Over 10	20-1	30-2

7 INSPECTION AND INSPECTION METHODS

7.1 Defect Criteria

Defects not otherwise covered in the specification which will not impair the performance of the finished instrument, shall be permissible. Whether a particular defect shall be permitted will depend on the location of the element in the finished optical system. Defects in element not near a focal plane are not as important as in elements which lie in or near a focal plane. In all instances, primary emphasis shall be placed on the performance of the lens or prism rather than its appearance unless the latter definitely indicates poor workmanship. The order or importance is as follows:

a) *Most Critical Surfaces*
   1) Etched surface of reticle, and
   2) Surfaces of collective lenses in the focal planes.

b) *Less Critical Surfaces*
   1) Surface of ocular field lens nearest the reticle; and
   2) Collective lens, centre lens or prism surfaces near a focal plane.

c) *Least Critical Surfaces*
   1) All other surfaces of windows; and
   2) Objectives, prisms, erector and eye lenses.

7.2 Cleanliness

Each optical component of a system shall be examined through the objective and eyepiece ends with the unaided eye. Inspection for moisture shall be made by the technique of shadowing. Inspection for dust particles shall be made by viewing a uniformly illuminated field having a brightness of approximately 300 apparent foot candles.

7.3 Cleaning Before Inspection

Before checking the surface quality of the optical components, the surface should be thoroughly cleaned to remove any grease films or other contaminations.

7.4 Inspection Method No. 1

The element to be inspected shall be viewed with a magnifier against a ground glass or opal surface illuminated from behind by a 40 W lamp.

7.5 Inspection Method No. 2

The surface to be inspected shall be obliquely illuminated by a 40 W lamp and viewed with a magnifier against a black matt surface. A simple viewing system is shown in Fig. 1.

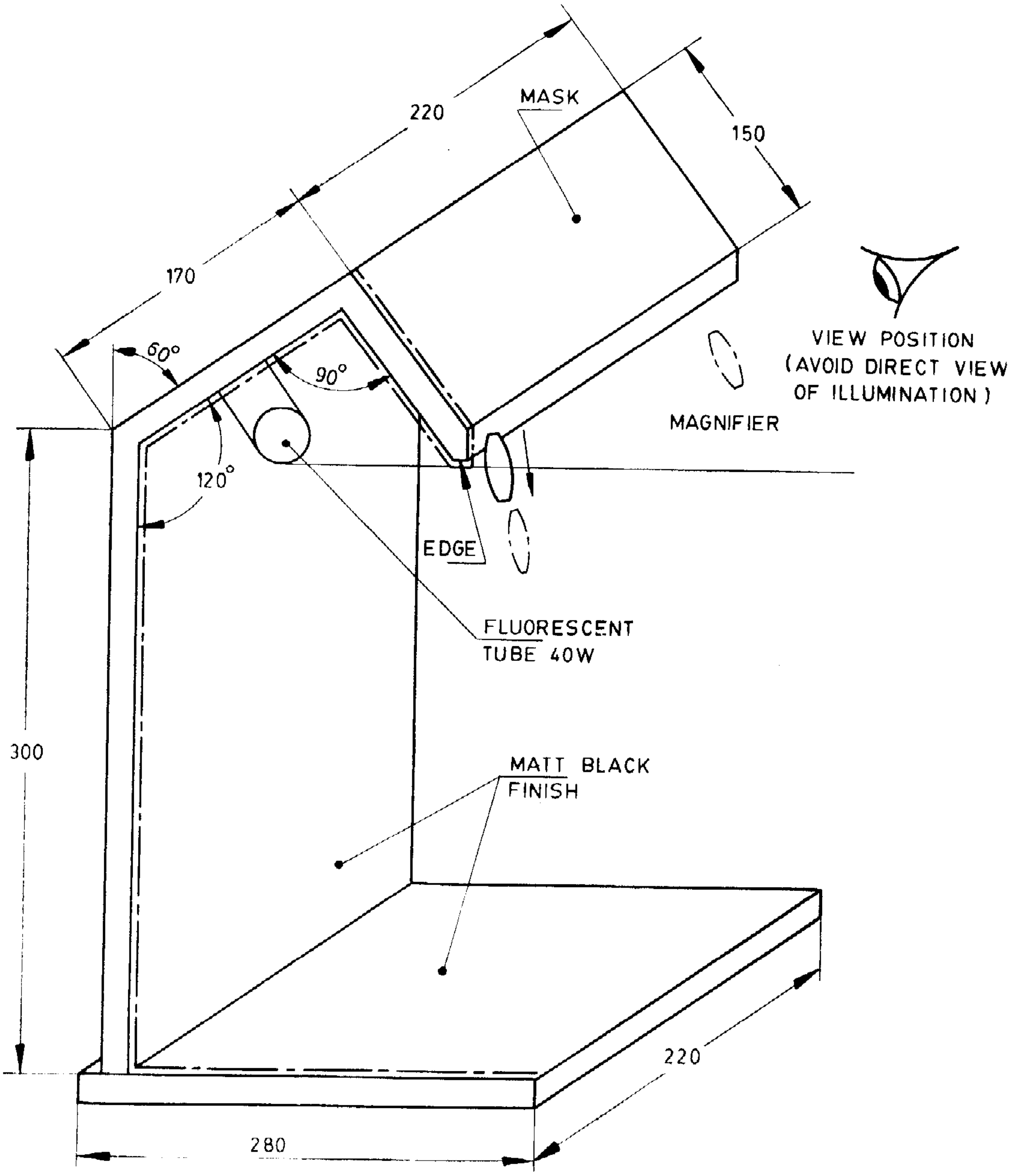
7.6 Selection of Magnifier for Inspection

7.6.1 For inspection of the element that belongs to 20-2 scratch-dig glass, the magnifier used should have its magnification equal to that at which the element would be seen in the instrument, but not less than 10 X.

7.6.2 For 40 - 20, 60 - 40, and 80 - 50 scratch-dig glasses, a magnifier having 6 X magnification shall be used.

7.7 A Typical Scratch-Dig

Specification with respect to beam diameter of an optical system is shown in Fig. 2.



All dimensions in millimetres.

FIG. 1 SIMPLE VIEWING SYSTEM

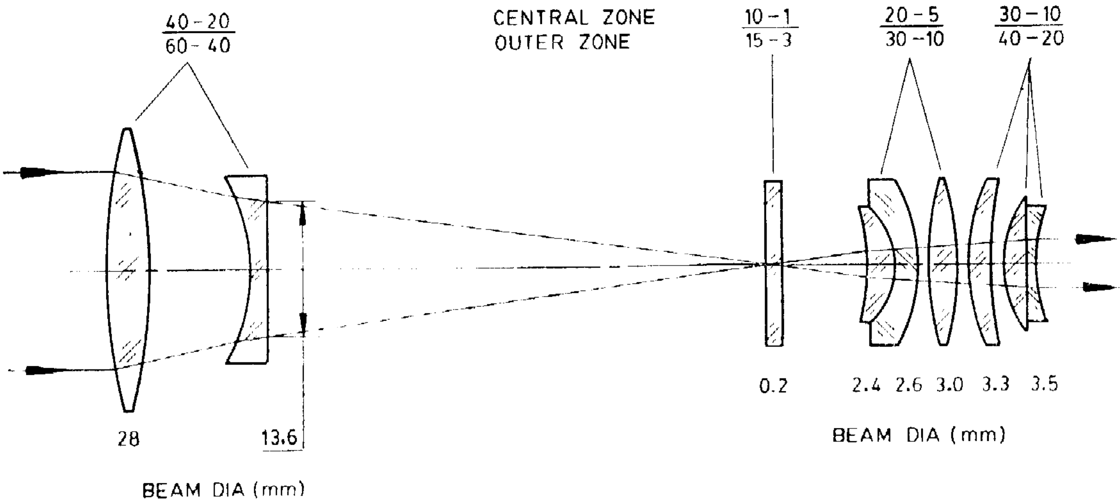


FIG. 2 SCRATCH-DIG SPECIFICATION

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